Identifying Malaria Hazard Areas Using GIS and Multi Criteria: The Case Study at East Gojjam Zone, Ethiopia

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Malaria is one of the most severe public health problems worldwide with 300 to 500 million cases and about one million deaths reported to date, 90% of which were reported from Sub Saharan African countries like Ethiopia. The main objective of the study was identification of malaria hazard areas by using the Arc GIS in East Gojjam zone. Weighted overlay technique of multi-criteria analysis was used to develop the malaria-hazard map. Temperature, rainfall, altitude, slope, distance from rivers, and soil types were considered as variables to prepare malaria hazard map. The malaria hazard map was classified into four suitability index such as very high suitable, high suitable, moderately suitable, and low suitable. The result shows that around 22% areas is highly suitable for malaria hazard, 27% is high suitable, 26% is moderately suitable and 25 % is low suitable for malaria hazard areas. It is suggested that effective identification and mapping of malaria hazard areas may contribute for the prevention system cost effective, least time taking, easily manageable in controlling the disease.

Key words: East Gojjam Zone, Arc GIS, Malaria.

INTRODUCTION

Malaria is a highly killer disease that affects majority of the world’s populations especially those people living in sub-Saharan Africa countries (Francis et al., 2016). It is estimated that at least 3.3 billion people globally are at risk of malaria infection. The disease is responsible for over half a million deaths each year, mostly (90%) in sub Saharan Africa (Onyango et al., 2016). Ethiopia is a predominantly malaria prone country as about 75% of the landscape of the country is favorable for breeding of the malaria vector (Embet et al., 2016). According to WHO, an estimated 627, 000 deaths occurred due to malaria in 2012 (WHO, 2012). In many developing nations with diverse ecological regions, malaria is still a large cause of human mortality (Francis et al., 2016, Bindu and Janak, 2014). Owing to the paucity in epidemiological data and their spatial origin, the quantification of disease incidence burdening basic public health planning is a major constrain especially in developing countries (Bindu and Janak, 2014).

Malaria as a vector borne disease whose transmission and risk levels depend on environmental factors, therefore, the distribution of malaria in Ethiopia is largely determined by altitude as it influence the temperature of the environ (Betemariam and Yayeh, 2002). One of the for instance, is temperature, as it affects mosquito development rate and final survival of the adult mosquitoes. Vegetation types, population density, poverty levels together with other development and social economic factors also greatly the influence malaria risk levels in a given locality (Francis et al., 2016).

Geographic Information System (GIS) is a novel technology that has evolved as a front runner in the study of the epidemiology of Malaria. Geographic Information Systems are a useful tool to generate interactive malaria hazard maps allowing the management and analysis of multiple databases taking into account the geographical component of the different hazard factors. Multiple criteria decision analysis approaches are used to deal with the difficulties that decision-makers encounter in handling...
large extents of complex information. The principle of the method is to divide the decision problems into smaller understandable parts, to analyze each part separately and then to integrate the parts in a logical manner (Malczewski, 1997). The purpose of this study is to use ArcGIS tools to identify the malaria hazard areas in the study area integrated with multi-criteria decision analysis method, which consists of the analytical hierarchy process (AHP) and weighted linear combination (WLC) methods.

MATERIALS AND METHODS

Study Area

East Gojjam Administrative Zone is one of the eleven Zones of Amhara National Regional State and constitutes 20 Woredas (16 rural woredas, and 4 town administration Woredas). It is bordered on the south by the Oromia Region, on the west by Mirab Gojjam, on the north by Debub Gondar, and on the east by Debub Wollo; the bend of the Abay River defines the Zone's northern, eastern and southern boundaries. Its highest point is Mount Choqa (also known as Mount Birhan). According from UTM coordinate system, the location of the town is approximately between 287743m – 449349m East and 1088275m – 1242618m North (Figure 1).

Methods

East Gojjam zone was selected to identify malaria hazard areas. For this Multi Criteria Analysis was used for creating various layers to be used in GIS domain to produce a single output map. The weights were developed by providing a series of pair wise comparisons of relative importance. Based on experience and likely impact on surrounding environment different weights were assigned to all the parameters. Weighted linear combination was used to produce the suitability of malaria hazard map. As for the final weighted factor map is a weighted linear combination of factor maps, an equation (1) as following:

\[ S = \sum w_i x_i \]  

where, \( S \) = suitability, \( w_i \) = weight of factor i and \( x_i \) = factor map i.
RESULTS AND DISCUSSION

Factors for Identify Malaria Hazard Areas

Slope

Slope is one of the topographical factors that have a bearing on the incidence of malaria. It is vital to include slope factor with other factors to assess for the malaria risk in community. This is because slope determines the mosquito’s larva habitat formation (Dilip et al., 2016). If a particular area that composed of steepest slopes, then there will be no chance of mosquitoes’ larva habitat formation, and hence area would have a negative influence to malaria incidence. If a particular area has a gentle slope, then mosquito’s larva formation is possible, hence leading to more positive bearing in malaria incidence.

Altitude

Altitude is one of the prominent factors; that was used to assess malaria hazard in the study area. The whole idea into integrating altitude factor for assessing the malaria hazard or risk is that of temperature difference within coast areas and mountainous areas of the study area. The higher terrain or high mountains have low temperature compared to low land areas that do have high temperature. Thus, mosquito’s habitats are well suited with low land areas, where the temperature is relatively higher. Communities living in highlands are subjected to fewer malaria incidence compared to communities living in low land areas where the chance of vector induced infections is high because most mosquito’s habitats are found in low laying areas. Higher altitude depics less malaria risk while low altitude depicts more malaria risk problems based on high or low temperature (Dilip et al., 2016).
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**Table 3: Classification, ranking and weighting of Altitude factor**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Weight</th>
<th>Class Range</th>
<th>Rank</th>
<th>Degree of hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altitude (meter)</td>
<td>0.35</td>
<td>840-1760</td>
<td>4</td>
<td>Very High Suitability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1760-2260</td>
<td>3</td>
<td>High Suitability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2260-2500</td>
<td>2</td>
<td>Moderate Suitability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2500-4060</td>
<td>1</td>
<td>Low Suitability</td>
</tr>
</tbody>
</table>

**Rainfall**

Rainfall plays a significant role in creating favorable conditions for malaria transmission and also the high source of water is more comfortable for malaria breeding. When there is a heavy rainfall, thus mosquito breeding is unfavorable during the rainy period since excessive rains cause flushing, thus killing immature stages to complete its life cycle to be an adult.

**Table 4: Classification, ranking and weighting of Rainfall factor**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Weight</th>
<th>Class Range</th>
<th>Rank</th>
<th>Degree of hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual rainfall (mm)</td>
<td>0.15</td>
<td>200-300</td>
<td>1</td>
<td>Low Suitability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>300-400</td>
<td>2</td>
<td>Moderate Suitability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>400-450</td>
<td>3</td>
<td>High Suitability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>450-500</td>
<td>4</td>
<td>Very High Suitability</td>
</tr>
</tbody>
</table>

**Temperature**

The ranges of minimum and maximum temperature greatly affect the development of the malaria parasite and its mosquito vector, which determines malaria transmission (Zewag, 2016). This indicates that, the temperature is greater than 40°C the malaria transmission is high and the temperature is below 16°C no malaria transmission (Ezeigbo, 1998).

**Table 5: Classification, ranking and weighting of Temperature factor**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Weight</th>
<th>Class Range</th>
<th>Rank</th>
<th>Degree of hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual temperature (°C)</td>
<td>0.2</td>
<td>16-18</td>
<td>1</td>
<td>Low Suitability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18-20</td>
<td>2</td>
<td>Moderate Suitability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20-21</td>
<td>3</td>
<td>High Suitability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21-23</td>
<td>4</td>
<td>Very High Suitability</td>
</tr>
</tbody>
</table>
**Distance from Rivers**

River is one of the various water bodies which are used for malaria transmission. Breeding of mosquito is related with different water sources. River is one among several of these Mosquito requires still or slow-moving water to lay its eggs and to complete its life cycle to be an adult (Alemayehu, 2011). Water diverted from rivers for different purposes and in case of over flow becomes still and favor mosquito egg laying. This influences the particular area with increased mosquito breeding and malaria prevalence. Conducting irrigation practices and developing agricultural projects around rivers can produce still water and as a result, the changing ecosystem can cause an increase in abundance of mosquitoes. The distance was reclassified based on the maximum distance that mosquitoes can fly.

**Soil Types**

The study area of soil data was obtained from minster of water and energy, Addis Ababa, Ethiopia (Abbay Basin Soil shape file). Based on Food and Agricultural Organization (2006), soil classification system, the study area consists of eleven soil types. The soil layer of the study area was classified according to their degree of hold moisture and being permeable or impermeable.

**Identified Malaria Hazard Areas**

In this study, some of the factors are considered to identify malaria hazard areas. The factors are elevation, slope, and distance from rivers, rainfall, and temperature and soil types of malaria occurrence in the study area. It determines number of occurrence of mosquitoes in an area, thus these leads to overlaying of each factor to establish and identify malaria hazard in an area. The malaria hazard map that was prepared was derived from several factors. The factors were ranked, according to the degree of importance that have for the occurrence of malaria in an area. Due to different opinions and views in assigning rankings and weightings to each factor and their classes based on the previous studies and experts by using weighted linear combination method. In this study, the final output map of malaria hazard after overlaying six factors namely; Altitude, slope, distance from rivers, temperature, rainfall and soil types was weighted and ranked in ArcGIS 10.4 using weighted overlay analysis tool, shown the following (Figure 9).
The area coverage of each suitability index of the malaria hazard area was calculated in ArcGIS environment showed that 840.24 Km² (25%), 857.07 Km² (27%), 894.60 Km² (27%) and 716.49 Km² (22%), representing of low, moderate, high, and very high suitability of malaria hazard areas respectively, with different suitability indices. Hence, it is possible to conclude that the majority of the area (more than 49%) is under high and very high hazard of malaria. From the finding result, the woreda of Gozamen, Baso liben, Awabel, and Dejen are high and very high of malaria hazard. This is due to the lower altitude and the higher temperatures for mosquito breeding.

CONCLUSION

This study was aimed at producing malaria hazard map of East Gojjam zone so that it can help to improve the management and control of malaria disease. This study has shown that the ArcGIS is important to identify malaria hazard areas for malaria disease control. The hazard map was produced depending upon the factors. The malaria incidence and transmission require the environment with lower elevation (higher temperature), occurrence of gentle slopes, and availability of still waters around rivers. Hence, from the result of the overlay analysis of the factors, it is possible to conclude that about 49% of the total area is a highly and very high exposed to malaria hazard.

REFERENCE


